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ERNST CLOOS

1898—1974

A Biographical Memoir by
AARON C. WATERS AND STEVEN M. STANLEY

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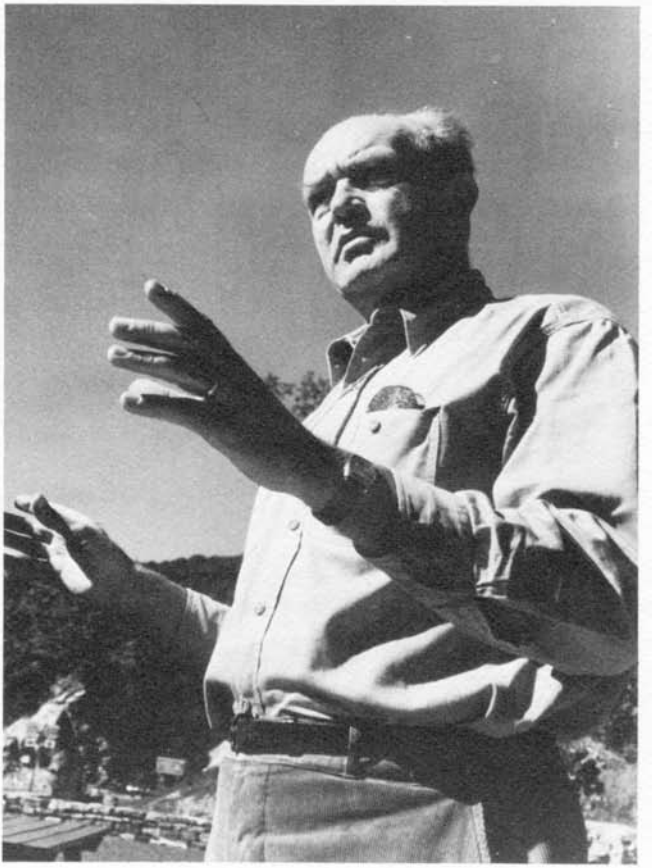

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Ernst Cloos

ERNST CLOOS

May 17, 1898–May 24, 1974

BY AARON C. WATERS AND STEVEN M. STANLEY

ERNST CLOOS' activities spanned that extraordinary interval from the horse-and-buggy days to the space age, a period of time that to young minds hardly seems compressible into one lifetime. An internationally renowned geologist, he also will be remembered as a remarkable man whose warm friendliness, insight, and humanity affected the lives of hundreds of people. Although he spent long hours and nearly every weekend at his teaching and research, Cloos nevertheless found time to respond to requests for advice regarding personal problems of the lowliest student, typist, or laborer. He was equally adept at resolving differences of opinion at the highest level of University faculties, in meetings of committees of the National Research Council, and among board members of large corporations.

Cloos was born in Saarbrücken, Germany on May 17, 1898 and died in Baltimore, Maryland on May 28, 1974. His early childhood was spent in Cologne, but after the death of his father, when Ernst was six years old, Frau Cloos moved to Freiburg im Breisgau, where Ernst's brother Hans, who was older by thirteen years, was a student in geology at the University of Freiburg.

Young Ernst performed indifferently at the local public school and spent three years at a religious boarding school in

the Black Forest. At age fourteen he was sent to the Hermann Lietz-Schule in Switzerland. Among the graduates of this unusual institution have been several luminaries, including Werner von Braun. It was here that the young Cloos found himself. Practical skills like woodsmanship were weighted equally with traditional academics. Agriculturally, the school was self-sufficient, and heavy outdoor work formed a major part of the program. The balanced curriculum appealed to Ernst, and he excelled. Whether the Hermann Lietz-Schule implanted traits in the boy or simply unlocked latent drives, his new enthusiasm for both academic and practical work was to last a lifetime.

Cloos' pre-university training, however, was interrupted by World War I. As a youth of seventeen, he volunteered for the Kaiser's army. Despite medical questions raised by the sound of his heart, he was granted admission to pilot school. He began the war pacifically enough by flying reconnaissance missions. Behind the cockpit of his biplane was stationed an observer-photographer. In the early days of the war, French and German pilots left the animosity of the conflict on the ground. Once aloft, they waved cordially in passing. As Cloos used to say, it was not until the damned American flyers joined in with their machine guns that his troubles began. One day over France, four of these villians appeared on his tail. Despite his best efforts at evasion, they gave pursuit for several miles and severely damaged his aircraft. This day, as every day, the young German flyer was mindful of the position of the Swiss border. With his engine failing, he glided to the safety of Swiss neutrality. Finding no area large enough for a normal landing, he brought his craft down in a field full of haystacks and set his course for one of them—the workers harvesting hay scattered as he approached. Years later, a son of one of these workers was by the sheerest coincidence a student in Cloos' classroom on the opposite side of the Atlan-

tic. One day on a field trip, the son heard his professor tell of the crash landing. Returning home, the student repeated the tale to his mother, who responded with amazement: "I know that man! I was in the field in Switzerland where he landed."

What the student's mother and her comrades in the hayfield found when they rushed to the plane was a dead observer and a dazed pilot, slumped forward, with his head against the motor. They revived the pilot, gave him food and water, and summoned the police. Young Cloos' airplane, riddled with nearly forty bullet holes, was placed in a Swiss museum. He himself was no less a curiosity, as a uniformed hero in a peaceful land. He was interned with the family of a friend from school days and permitted to reenter the Hermann Lietz-Schule where he made good use of his time by completing the studies that prepared him to enter the University at Freiburg.

Released from Swiss internment with the coming of peace, young Cloos returned to the Germany of *All Quiet on the Western Front*, the Germany of a lost generation. He rejoined his family in Freiburg and enrolled at the University to prepare for a career in biology. Like nearly all veterans returning from war, Ernst Cloos had difficulties in concentrating on his studies. He nearly left Freiburg to fly airplanes in Mexico, but his biology professor persuaded him that continuing his studies offered a far better opportunity for building a career. Nevertheless, as his education in biology advanced, the student became more and more frustrated as he sat on a stool hunched over a laboratory bench peering at almost invisible animals. Did not his brother's profession offer a new opportunity, and far more freedom?

Ernst's brother, Hans Cloos, had studied geology at Freiburg, and later worked as a geologist in the Erongo Mountains of Southwest Africa and in the oil fields of Indonesia. In 1919, at age thirty-four, Hans Cloos was appointed to the

Chair of Geology at the University of Breslau (at present in Poland, and renamed Wroclaw). In his autobiographical book of geologic travels, *Gesprach mit der Erde* (R. Piper, Verlag, 1947), Hans Cloos speaks vividly of his astonishment at finding his younger brother on his doorstep in Breslau:

> "I have got to lay my hands on something solid," he said as for the last time he cleaned and laid aside the hair-fine glass needles which for a whole year he had been using to coax invisible abnormalities from his almost invisible animals, or to add them where none had been before. With this he put his hammer in his knapsack, and exchanged the dampest and greenest corner of Germany for that other corner where, through a thin forest cover, the bare rocks of the mountains look out, clear and enticing. . . .
>
> "I can't endure sitting down any longer," the big, broad-shouldered man said to his astonished brother. "I want an existence where I can move around freely, where I can tread as hard as I like without breaking something. I'm sick of tiny little lumps of slime. I want to lay my hands on big, hard mountains! I want to become a geologist!"*

At Breslau Ernst Cloos met and became firm friends with Robert Balk, born in Riga on the Baltic. Balk almost simultaneously had decided to give up his interest in hummingbirds and other "living organisms for the realm of the dead rocks."† Their friendship lasted a lifetime. Both were destined to come to the United States, where they had outstanding careers as university professors. Each student chose to work for his doctorate on the granites and gneisses of Bohemia, using the methods of "granittektonik" that the older Cloos had made famous in Europe. Food was scarce in Bohemia after World War I, and German money was almost worthless. At times the two students virtually had to "live off the land," but the rocks were exciting and well-exposed on mountain slopes and in numerous quarries. Moreover, a raw

*Hans Cloos, *Conversation with the Earth* (New York: Alfred Knopf, 1953), p. 351.
†*Ibid.*

potato or cabbage could sometimes be gleaned from the fields between. Each student completed the reports on his field work, and each was awarded the doctorate with highest honors in 1923.

To what extent the elder Cloos served as surrogate father to the younger can only be speculated upon, but the ability of the two to prosper as professor and student is a tribute to both men. Each brother held a great fondness and admiration for the other, and to this strong sibling bond Robert Balk was admitted as another close "brother." Yet the three were very different in temperament and in physical stature. Hans Cloos, a small wiry man of tough mind and principles, was a brilliant lecturer and writer. Robert Balk was quiet, introspective, and even-tempered. Ernst Cloos' difficulty with biology was not entirely a matter of intellectual boredom. The problem here was that the younger Cloos was also by far the larger brother. A giant for this generation, he stood well over six feet tall and weighed over two hundred pounds. Even as a septuagenerian, his friendly slap on the back could set one to coughing. The man simply was not built for glass needles and microscope slides.

Nevertheless, Ernst Cloos did reap a real reward for his years of studying biology at Freiburg: on receiving his doctorate at Breslau he returned to Freiburg and married Margret Spemann, the daughter of his biology professor! Many years later no one was prouder than Ernst Cloos when Professor Spemann won the Nobel Prize for his studies of the "little lumps of slime" that his awkward student had so cavalierly rejected!

Worthwhile positions in geology were almost nonexistent for new Ph.D.'s in the Germany of 1923. Robert Balk emigrated immediately to the United States. In the course of his graduate education, Ernst left Breslau for a brief interlude to study at Göttingen under the famous Hans Stille. Now, upon

graduation from Breslau, he was offered a position as Stille's assistant, a miraculous opportunity in the perilous postwar economy. But on the night before the wedding, with the Spemann house filled with guests, a telegram arrived. Tragically, the state had cancelled the position with Stille. In this unforeseen crisis, the advice of Professor Spemann was for the couple to proceed with the wedding and to take up residence in Göttingen, hoping that a position might appear. The advice was heeded; Ernst did find work at a menial curatorial job in Stille's department, but the pay was a paltry ten pounds of flour a month!

Some thirty pounds of flour later, Cloos secured a position with one of the first companies ever to apply seismic exploration toward the discovery of oil. Lutger Mintrop, the founder of this company (Seismos), assigned Cloos to work first in the swamps along the Gulf Coast of Texas and Louisiana, and later in the scorched deserts of Iraq. Although the work was timely and interesting—it ultimately developed into the major method of discovering oil adjacent to salt domes, and in offshore parts of the continental shelves—the areas selected for study were not attractive places to bring a bride, or to start a family. Margret endured the humid Texas swamps, but was not permitted in the oil fields of Iraq. Moreover, after a few years Cloos became bored with the routine of "setting off huge blasts of dynamite and studying the squiggles that the artificial earthquake waves produce on a sheet of paper."

In 1930 Prussia's director of geologic studies made it possible, by a small grant from the Notgemeinschaft der Deutschen Wissenschaft, for Ernst Cloos to study the granitic rocks of the Sierra Nevada. He resigned his well-paying job with Seismos and headed for California.

During the next two field seasons Cloos roamed over the barren peaks of the high Sierra plotting on maps thousands

of structural readings of the cracks, schleiren, lineations, mineral banding, dikes, and other subtle features that record the motion of granitic and granodioritic masses during the final stages of their emplacement and consolidation within the earth's crust. The science of "granite tectonics" was new in America, and his first report on the Sierra Nevada, although published in German, drew attention from American scholars, and also an awareness of the publications of his brother, Hans, who developed these techniques during investigations of European and African igneous massifs.

A fortunate turn of events for the Cloos family, and also for Appalachian geology, occurred in 1931 when Ernst Cloos was on his way to Europe after completing his Sierra Nevada field work. On a tip from Robert Balk, then professor of geology at Hunter College, Cloos drove his battered California field auto to Baltimore in order to visit the Geology Department at Johns Hopkins University and inquire about a possible opening for a lecturer. At the end of the visit E. B. Mathews, chairman of the Department, invited Cloos to "stay a little longer." Margret Cloos, on receiving this news, found temporary care for their two small daughters at a nursery home in the Black Forest and crossed the Atlantic to join her husband. The lectureship was renewed each year, but the young couple could not plan on the position becoming permanent.

In 1933 news of Hitler's ascendency reached the Clooses at a cocktail party in Baltimore. Other guests, knowing little about German politics, were surprised at the couple's great agitation. Ernst, forthright as usual, predicted the eventual onset of World War II, and announced to all that he would not return to Germany. Margret did, briefly, to gather up her children and the couple's personal belongings.

The decision to remain in America during the most bitter year of the depression required courage ("after all if I lose my

job I can open a filling station in Death Valley," Ernst joked), but it also brought intangible benefits. The feeling of "marking time" while waiting for an academic position in Germany was ended. A more important benefit was that Ernst realized that he should now start on larger and more complex projects of the local geology, and bring them to completion.

Cloos' impact upon prevailing ideas of the geology of Maryland began almost from the moment he arrived in Baltimore. Much of his research time in his first two years at Johns Hopkins was spent writing reports (in English) on the Sierra Nevada work and in preparing a report on the Loon Lake batholith in eastern Canada, but whenever a free day appeared he used it to investigate the structure of the gneiss domes and granitic bodies near Baltimore. A year or two later he and his students were ranging farther afield among the greenstones, quartzites, slates, and limestones of the Appalachian Province at Harpers Ferry, Peach Bottom, South Mountain, and the Virginia Blue Ridge. Most American geologists had assumed that the geologic mapping of Maryland was completed, principally by state and federal surveys, but the remapping of certain areas in more detail with Hans Cloos' techniques brought major changes in geologic interpretation of some areas. Soon Cloos and his students were writing articles on Piedmont and Appalachian geology, giving examples of the application of the new structural methods to local rocks.

Cloos' methods of teaching proved as original and novel to his American colleagues as did his work on the local rocks. Unlike his brother Hans, Ernst Cloos deplored formal lecturing in the classroom, holding that discussions about rocks are more stimulating and most informative when held on the outcrop, where additional evidence can be garnered immediately if differences in interpretation arise. He scheduled his structural geology class for "All Day Saturday, in the Field,"

and this did mean "All of Daylight." Office discussions with a graduate student (or with a visiting colleague) were likely to end shortly with the invitation: "Let's go to South Mountain [or other appropriate locality] and see!" Gasoline ranged from 9¢ to 11¢ a gallon (including taxes!) in the nineteen-thirties, and a good second-hand field car could be had for thirty-five to fifty dollars. Moreover, Johns Hopkins was a mature university whose red tape was held to an absolute minimum. Cloos did not have to fight the battles with committees of "Educational Policy," "Scheduling," "Registration," "Safety," "Credits," and "Academic Policy" that would have cramped his style in a large American state university.

During the depression years few young faculty members in American universities dared raise questions of "tenure," but by 1937 the tenuous lectureship at Hopkins was straining Cloos' patience to the point where he began to look elsewhere. An offer of permanent status came from Wisconsin. When it was presented by Mathews to Isaiah Bowman, the University president, Bowman's response—long cherished by its subject—was, "Good for Cloos." Not an assistant professorship but an associate professorship was immediately offered and accepted. The attachment to Hopkins became permanent. At last Margret Cloos, her husband, and children had a home.

At first Cloos' reinterpretations of Maryland geology aroused strong objections from some local geologists who had relied solely on petrologic mapping, and had neglected structural methods in reading the record imprinted in the rocks. One cutting remark irritated, but also stimulated Cloos to widen the scope of his own inquiries: "The trouble with Cloos and his students is that they are so busy mapping the cracks and lineations in the rocks that they don't see the rocks between the cracks." Cloos decided he must learn how to use the petrographic microscope.

It is an interesting coincidence that George Huntington Williams, the first professor of geology at Johns Hopkins University, had elected to go to Germany to study for his doctorate. He brought home to America the new method of investigating rocks in thin sections by means of the petrographic microscope. Williams was the first great teacher of petrography in America. Among his early pupils who took their doctorates at The Hopkins were Andrew C. Lawson, Florence Bascom and William Herbert Hobbs. The petrographic microscope caused a major revolution in the geologic sciences near the end of the nineteenth century. Cloos, however, had never taken a course in petrography in college. By that time in Germany, mineralogy and petrography were well-established branches of the earth sciences, usually taught in a separate department. Williams, of course, had died long before Cloos arrived at Johns Hopkins, but the excellent collections of rocks and thin sections that he brought from many classical localities in Europe, and the extensive collections of local Maryland and New York State rocks that he added later, were in the Johns Hopkins laboratories along with several large bound ledgers filled with notes and descriptions written in Williams' exquisite classical penmanship.

Cloos' effort to become a "self-taught" petrographer with the aid of Williams' notes and collections was only partly successful. Always an innovator, he soon merged his newfound interest in the petrographic microscope with "gefugekunde"—generally translated into American English as "petrofabrics"—a new line of microtectonic investigations developed by Professor Bruno Sander of Innsbruck. After all, quartz and mica are readily identified under the petrographic microscope, and the plotting of their axes by means of a microscope equipped with a universal stage appealed to Cloos' almost military penchant for order, symmetry, and detail in everything he did. Cloos soon adapted Sander's

method of presenting data in contoured petrofabric diagrams to his measurements of cracks, lineations, and other structural elements in the field. Now on Saturdays, if a snowstorm or muddy country roads prevented field work, Cloos and his students busily plotted their field and thin-section data into the "equal-area net," oriented with north at the top as in a map, and contoured the results into fabric diagrams.

Out of this happy symbiosis of old and new methods came many excellent publications. Moreover, Cloos' "education" in petrography and petrology received a great boost from a truly exceptional group of postdoctoral and predoctoral students who came to work with him. Many were well-grounded in petrography from studies at other universities. The joint monograph of Cloos with Anna Hietanen: "Geology of the 'Martic overthrust' and the Glenarm Series in Pennsylvania and Maryland," published in 1941 as Special Paper 35 (207 pages) by the Geological Society of America, affords an outstanding example. Trained under the world-famous petrologist Pentti Eskola in Finland, Anna Hietanen had also sharpened her expertise on petrofabrics through her investigations of Finnish quartzites. She worked with speed and precision in determining the petrography of the Maryland and southern Pennsylvania rocks. During her two-year postdoctoral fellowship at Bryn Mawr and Johns Hopkins, Cloos gained much help in overcoming his petrologic handicap. Their monograph put a stop to the old controversies, and as Francis Pettijohn wrote many years later, "This monograph went far toward building a solid foundation for understanding the fundamental problems of the Appalachian geosyncline. It was a 'quantum jump' ahead of earlier work and set a standard not yet surpassed."* Later, doctoral stu-

*Francis Pettijohn, "Memorial to Ernst Cloos 1898–1974, *Geological Society of America, Memoir* vol. 6 (1977).

dent James G. Moore helped Cloos revise a few of his interpretations of the Sierra Nevada rocks, and, contemporaneously, doctoral student Clifford A. Hopson showed that some "granite" massifs in the Maryland Piedmont were really metamorphosed sediments instead of igneous granites. Both cracks and rocks were now being looked at—and in great detail.

Cloos had already published papers about the South Mountain fold, but with these new tools he decided to detail the strain features shown in the oöids within the oolitic limestone deformed by this fold. Oöids are spherical, sand-sized grains, which commonly form on the seafloor in shallow tropical areas like the modern Bahama Banks. They frequently become incorporated into sedimentary rocks, like certain of the limestones that have been folded into the Appalachian Mountains. Under great pressure in the building of the Appalachians, spherical oöids became stretched into ellipsoids, tracking the course of deformation of the rocks that held them prisoner. With characteristic German thoroughness, Ernst Cloos measured myriads of these diagnostic grains. His view was that broad trends, extending over many miles, can be interpreted by extrapolation from highly detailed local analysis of the strain features in the oöids. His famous paper "Oolite Deformation in the South Mountain Fold, Maryland" (*Geological Society of America Bulletin,* 58 (1947): 843–917) reached a far greater audience than his papers on structural geology of granite. Demand for reprints was so great that Cloos had it republished at his own expense. This paper, and the joint monograph with Anna Hietanen undoubtedly gave the impetus for Cloos' election to the National Academy of Sciences (1950), and to the American Philosophical Society (1954). Meanwhile other new methods were casting light on the geologic evolution of the crystal-

line rocks of the Appalachians and Piedmont. After some false starts and early difficulties, radiometric dating suddenly "came of age." With the use of the concordia curve and of isotope studies, radiometric dates unraveled some snarls in reading the histories of the gneiss domes, the Glenarm Series, and equivalent rocks in other parts of the Piedmont. Although Cloos took no part in these geochronologic and geochemical investigations, he aided in getting the equipment and staff needed to modernize the laboratories at Johns Hopkins, and helped in arranging a joint program with the Geophysical Laboratory in Washington. Moreover he was a stabilizing critic in emphasizing that a batch of radiometric dates unrelated to structural and stratigraphic studies are no more informative of earth history than a barrel of miscellaneous rocks and fossils gathered at random.

The importance of these additional methods, and also of the contribution made by the program of paleocurrent studies which Professor Francis Pettijohn brought to Johns Hopkins in 1952 can be seen by leafing through the book *Studies in Appalachian Geology* (New York: Interscience Publishers, John Wiley, 1970, 460 pages). This book, planned to honor Cloos when he became Professor Emeritus in 1968, contains contributions by thirty-three of Cloos' former students and colleagues. The book is dedicated: "To Ernst Cloos who rekindled a spirit of inquiry into Appalachian geology."

A controversial problem discussed in this book is whether the basement rocks of the Piedmont were involved in the deformation that produced the Appalachian folds, or whether this deformation was "thin-skinned"—with the Paleozoic sedimentary rocks merely gliding over the basement rocks like a rug crumpled across a floor. With characteristic energy, Cloos turned his attention to this problem after "retirement." He knew that in the northern extension of

the Blue Ridge (called South Mountain in Maryland) the crystalline rocks that lie beneath the oolitic limestones and Catoctin greenstone (a belt of slightly metamorphosed basalt lavas) are elevated to heights several kilometers above their level in the Ridge and Valley Province to the west, where they lie beneath folded sedimentary rocks. Could the strain produced by this period of folding, which he had so successfully measured by the changes in shape of oöids in limestone, be traced and correlated with other structures present in the greenstone and gneissic rocks, as well? Fortunately several patches of oolitic limestone are infolded with the much more voluminous greenstone and gneiss of the Blue Ridge to James River, 200 miles south of South Mountain. These patches became keys to a solution. During renewed visits to South Mountain during the late 1960's, Cloos noted that a relation exists between the direction of the longest axis of deformed oöids and the direction of certain lineations and streaks of new mineral deposition in the greenstones and gneisses. The refinement of these observations, and extension of the field work to cover an area 200 miles long and 30 miles wide enclosing the Blue Ridge is reported in a book *Microtectonics Along the Western Edge of the Blue Ridge, Maryland and Virginia* (Baltimore: Johns Hopkins Press, 1971, 234 pages).

The astonishing conclusion from this work is that during the folding of the sedimentary rocks, all formations, including those of the crystalline basement, received an imprint of easily recognized microtectonic structures over the entire area covered, and to a stratigraphic depth of at least six miles. On pages 78 and 79, Cloos lists the microtectonic structures that can be used for each formation, from the oldest Precambrian gneisses to the Devonian Romney Formation. The amazing uniformity of the pattern of deformation through-

out this thick and widespread succession of rocks is best stated in Cloos' own words (page 79):

> This simple pattern [of deformation] is universal in all diagrams and [for] all formations from the Precambrian gneisses to the Silurian. The deformation plan [for the whole area] is identical with that reported for South Mountain, Maryland. . . . The elements are common everywhere, can be identified in the field, in [sawed] specimens, and in thin sections. There can be little confusion if the coordinates can be so easily recognized.

Cloos' beautiful book, certainly a milestone in Appalachian geology, reveals much about its author as well as about the rocks. The text is short—it occupies less than one-third of the space in the book. Eighty-seven pages of half-tone plates, forty-seven carefully hand-drawn figures, thirteen tables, and twenty-three pages of an appendix labeled "Raw Data" make up the rest. Literally tens of thousands of field observations are recorded in diagrams. So great is the mass of data that it almost amounts to overkill. If only Professor Spemann had lived to see this memoir! Impatient long ago with "little blobs of slime," his student (and son-in-law) had now produced wonders from little blobs of rock through his patience and painstaking detail. Appropriately, Cloos dedicated the book "To the Memory of Robert Balk," who lost his life in an airplane crash.

Ernst Cloos' introduction of microtectonic techniques, of the sort pioneered by Bruno Sander and Hans Cloos in Europe, to problems of the Appalachians came at a logical time. By these techniques, small-scale rock deformations are analyzed both in the field and in thin sections, and the results extrapolated to the scale of mountains and valleys. The inception of the techniques in Europe presumably reflected the relatively early completion of regional geologic mapping, which was succeeded in the first half of this century by more

detailed field work, and by micrometric analysis. Across the Atlantic, New World geologists were still assembling the broad geologic outlines of a vast continent. Not surprisingly, it was immigrants like Cloos and his friend Robert Balk who initiated microtectonic studies in America.

Thus far we have written about Ernst Cloos' accomplishments as investigator and teacher. He was equally gifted as a leader of people. Perhaps because of his commanding size and strong personality, his leadership was felt immediately in any group or committee. He was a forceful and decisive executive. As an arbiter who possessed an unusual sense of wisdom, he was elected to the Academic Council of the Johns Hopkins faculty almost every year from 1948 to his retirement. In this work he was noted for insistence on high standards, but also for the kindliness with which he terminated a "sticky problem."

In 1950 a Johns Hopkins evaluation committee recommended that the Geology Department be upgraded—after G. H. Williams' days it had declined in stature. President Detlev Bronk immediately appointed Cloos to the chairmanship. Within a year Cloos persuaded Francis Pettijohn and Aaron Waters to join the faculty, and later added younger men: Clifford A. Hopson and Hans Eugster. The small department regained the position it had once held among the nation's top graduate schools in geology. One indication was the outstanding graduate students (most of them bringing NSF predoctoral fellowships with them) who elected to work for their doctorate at Johns Hopkins. Those admitted came from widely different parts of the United States, Canada, and Europe, thus aiding in bringing diversity and new ideas to what had formerly been mostly a local student body. Many persons who become chairmen of academic departments at universities view their jobs as thankless undertakings appreciated only by a few local beneficiaries. Seldom does a chair-

man succeed so spectacularly as to be nationally acclaimed for his administrative efforts. Ernst Cloos was such a chairman.

Cloos chaired the Division of Geology and Geography of the National Research Council from 1951 to 1954. He accomplished this duty by spending every Friday in Washington, D.C.

Cloos served as acting director of the Maryland Geological Survey during 1963, and led the search for a permanent director. During this year he also completely rewrote the Survey's charter and changed its objectives, reducing regulatory activities and providing employees with greater freedom to engage in productive scientific research.

Throughout his career Cloos maintained an interest in those corporations that employed geologists. He was hired as a part-time consultant by numerous companies, but eventually narrowed these activities to the Thomasville Stone and Lime Company of Pennsylvania, and the Esso Production Research Corporation in Houston, Texas. As geologist for the Thomasville Company, he supervised exploration (by drilling) at their limestone quarry. When the surface outcrops had been largely removed, he persuaded the Company to follow the ledge underground in a mining operation. The huge caverns that resulted proved economically feasible, and the Company is still producing from them.

For Esso Production Research, one of the tasks that Cloos particularly enjoyed was running a seminar course in structural geology, or in his words as a "Maker of Mud Pies." Each year he went to Houston for a period of a week or ten days and set up scale-modeling experiments, using a soft white clay mixed with water until it was scaled down in strength to simulate approximately the behavior of rocks that are folded and fractured within the much larger dimensions of the crust of the earth. Before an appreciative audience of Esso trainees, geologists, executives, and other Texas geologists who

were invited to participate, Cloos demonstrated his talents as master mud-pie maker by deforming the wet clay, and causing it to change before their eyes into miniature near-replicas of the folds, graben, salt domes, and basins of the kind that guided their search for oil. It is claimed that these sessions were conducted in a more relaxed atmosphere and with far greater levity than the same experiments done in the Johns Hopkins structural geology laboratories on snowy winter mornings. There, perhaps because the weather prevented the pie maker from teaching in the field, woe came to the unlucky student who drowsed off during the slow emergence of a structure, and thus did not immediately notice, measure, record, and sketch the appearance and changes in the cracks, striations, and minifolds as they evolved from the wet clay.

These scale-modeling sessions in Houston were the inspiration for another of Cloos' research papers. Through discussion with the Houston geologists he became interested in trying to model the structure of the entire Gulf Coast Province, an area where he had first worked in 1924 as a young recruit in geophysics for Seismos. Cloos' article, "Experimental Analysis of Gulf Coast Fracture Patterns," published in *American Association of Petroleum Geologists Bulletin* (vol. 52 (1968): 420–44), won for him the Association's Presidents Award.

He received many other honors. Already mentioned was his election to the American Philosophical Society and the National Academy of Sciences. He received a Guggenheim fellowship in 1956. He became a foreign member of the Finnish Academy. He received the Gustav Steinmann medal of Germany's Geologischen Vereinigung in 1968. He represented Johns Hopkins University at the celebration of the 500th Anniversary of the University of Basel in 1960, and also at the 100th anniversary of the National Academy of Sciences in 1963. His long and outstanding services to Johns

Hopkins University were recognized by the conferring of an L.L.D. in 1973.

In addition to the major American geological societies, he was a member or fellow of the Geological Society of Canada, Geological Society of London, Geologischen Vereinigung (the Geological Society of West Germany), and the Geological Society of Finland. Although his greatest contributions were to American geology, and especially to the structure of the Appalachians, his influence on the development of structural geology was worldwide.

For those colleagues and students who worked with Ernst Cloos, and who knew him well, the feelings evoked by news of his death are well summed up in two short sentences written by Professor O. M. Phillips, chairman of the Department of Earth and Planetary Sciences at Johns Hopkins University: "In my life I have known but few great men, a very few, and Cloos was certainly one of them. We will miss him more than we know."

Margret Spemann Cloos survived her husband, and now lives in Pennsylvania. The homes of their two daughters are also in the United States: Gisela (Mrs. W. R. Evitt) lives in California, and Veronica (Mrs. F. C. Evering) in Vermont.

MANY PASSAGES in this memoir are taken directly, or closely paraphrased, from a memoir that one of us (Waters) wrote for the American Philosophical Society. We have also had the advantage of access to data in Francis Pettijohn's Cloos memoir for the Geological Society of America. The bibliography up to 1968 is modified from the previously referenced book *Studies in Appalachian Geology*. Margret Cloos' kindness in checking dates, and providing information about Ernst Cloos' early life in Germany and America is greatly appreciated.

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